MRI of anorectal diseases

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MR imaging of the anorectal region primarily concerns rectal cancer and perianal fistulas and to a lesser extent other conditions such as fecal incontinence.

MR imaging

Sequences

MR imaging of the anorectum primarily comprises T2-weighted fast spin-echo sequences in multiple directions using external phased array or SENSE coils. Optimal contrast between the different components of the anus and rectum and surrounding structures can be obtained with moderate T2-weighted turbo spin-echo (e.g. TR 2500 msec; TE 70 msec, etl 16, FOV 300, matrix 256 x 512, slice thickness of 3-4 mm, nex 2) although parameters have to be optimized for the MRI field and system used [1].

T1-weighted sequences have limited additional value, except in patients with perianal fistulas where contrast enhancement differentiates between an abscess and a cavity filled with granulation tissue. Without intravenous contrast medium the distinction between the sphincter components is more difficult than at T2-w FSE. There is no definite additional value of intravenous contrast medium for determining the presence and extent of disease, although in individual cases contrast medium enhanced T1-weighted sequences might be helpful [2,3].

Coils

Endoluminal coils give the possibility of increased spatial resolution for a limited field of view, but the application of these coils is not widespread. Superiority of endoluminal coils over external coils for anorectal imaging has not been demonstrated, except for body coil MRI [4-6]. In rectal cancer, external phased array coils will be used. For perianal fistulas, most institutions will use external phased array coils. We also use external coils in patients with perianal Crohn's disease. We have adopted a somewhat different approach in patients with cryptoglandular perianal fistulas, as identification of the internal opening is relevant to many surgeons. Theoretically, endoluminal coils might have an advantage as the internal opening (a findings important for several treatment strategies) is often small and higher local spatial resolution can be valuable. Although advantageous as compared to body coil, this has not been studied in comparison to external phased array coils except for a small series. In patients with fecal incontinence endoluminal MRI is more widely used than external coil MRI, and endoluminal MRI has a specific role in patient management (sphincter defects, external sphincter atrophy). The use of an endoluminal coil might result in patient discomfort, and this primarily concerns some patients with perianal fistulas were coil introduction can be painful. As the advantage of endoluminal MRI for perianal fistulas has not been demonstrated, the use of an external coil is an obvious solution. Combining endoluminal coils and external coils may combine advantages of both coils, but this has not been studied for anorectal imaging.

Patient preparation

Patient preparation is limited. At our institution we ask patients to fast four hours prior to the examination and to visit the bathroom directly prior to the examination. We do not use enteral

contrast media, although some centers advocate the use of rectal contrast medium in patient with rectal cancer to facilitate identification of the tumor. In our experience identification of the tumor is easy in almost all patients, although this might be influenced by the spectrum of disease. As patient with small, superficial tumors (T1) are better studied with endosonography, we primarily examine patients with higher T-stages (T2 and higher). The use of bowel relaxants is controversial. In Europe butylscopalamine (Buscopan, Boehringer, Ingelheim, Germany) is available, which is most likely preferable to glucagon. We use Buscopan for endoluminal imaging as these examinations are more sensitive for motion artifacts caused by bowel peristalsis, while in external coil MRI the use depends on the application. In practice Buscopan can be applied when the initial sequence has substantial artifacts.
With the use of endoluminal coils the use of supportive pads is important to increase patient comfort and reduce motion artifacts. Patients should be asked not to squeeze or contract their pelvic floor muscles to prevent motion artifacts at endoluminal imaging.

Anorectal anatomy

The term rectum is loosely used and most often an external reference point (e.g. the sacral promontory) is used for the begin of the rectum. The rectum is not a straight structure but instead is composed of three lateral curves. The rectum can gain in length either during a diagnostic procedure or postoperatively, causing some difficulty in localizing a lesion by measuring it from the anal verge.
The rectum has a layered anatomy comprising the mucosa and submucosa, the muscularis propria (lamina propria; the inner circular layer and the outer longitudinal layer), and the surrounding mesorectal fat. With MRI using T2-weighted images, the muscularis propria can be identified as a relatively low-intensity structure, distinct from the relatively hyperintense inner (sub)mucosal layers and the relatively hyperintense outer mesorectal fat. After intravenous contrast medium there is no substantial enhancement. The mesorectal fat envelope is bordered by the mesorectal fascia, an important anatomic boundary for rectal cancer management.

The anal sphincter is a cylindrical, multilayered complex that is tilted in the sagittal plane, with the superior part more anteriorly than the inferior part [7]. The canal is 4–6 cm (average 5 cm) in length. Innermost is the anal lining - (sub)mucosa/(sub)epithelium -, and subsequent layers comprise the internal anal sphincter, the fat-containing intersphincteric space with the longitudinal layer, and the external sphincter and puborectalis (pubovisceralis) muscle. Outside the anal sphincter is the fat containing ischioanal (formerly named ischiorectal) space.
Most important parts for imaging concern the muscular components and the fat-containing intersphincteric space between the sphincters. The more inner smooth muscle circular internal anal sphincter is the continuation of the circular layer of the muscularis propria of the rectum. This layer increases in thickness (approximately 2.8 mm at endoluminal imaging) below the anorectal junction to form the internal sphincter [8]. The sphincter has an important role in maintaining continence and is the main contributor to anal rest pressure. The internal sphincter is relatively hyperintense at T2-weighted sequences with a homogeneous, uniform architecture. When intravenous contrast medium is administrated, avid enhancement of the internal sphincter is seen at T1-weighted sequences.

The outer striated muscular layer of the anal sphincter comprises the external anal sphincter as lower part and the sling-like puborectal muscle as upper part. These muscles delineate the outer border of the anal sphincter. Action of the external sphincter is voluntary closure and reflex closure of the anal canal and it contributes to the sphincter tonus to some extent. The external sphincter is approximately 2.7-cm high while it is shorter anteriorly in women, approximately 1.5 cm [8]. The lateral part of the external sphincter is approximately 2.7-cm high. The external sphincter has a thickness of 4 mm at endoluminal imaging. The external sphincter extends

approximately 1 cm beyond the internal sphincter and envelops the lower part of the intersphincteric space.
The puborectal muscle is part of the levator ani muscle that includes two other parts: the iliococcygeus and the pubococcygeus. The latter two form the levator plate and, together with the coccygeus muscle, the pelvic diaphragm. These striated muscles are relatively hypointense at T2-weighted images and show no or only slight enhancement after intravenous contrast medium.

Rectal cancer

Rectal cancer primarily concerns adenocarcinoma. Treatment of rectal cancer depends on the extent of disease and has changed substantially over the last decades. Tumor limited to (sub)mucosa (T1 disease) is often treated by transanal endoscopic microsurgery. Endosonography is preferable for local staging of these tumors. The higher spatial resolution of endosonography as compared to MRI facilitates a more detailed demonstration of the rectal wall layers. This leads to a significantly higher ($p = 0.02$) specificity of endosonography (86%) as compared to MR imaging (69%), indicating overstaging of T1 (or lower) tumors with MR imaging [9]. Endoluminal US and MR imaging have similar sensitivity estimates of 94% for these tumors.
Often, the tumor is more advanced than (sub)mucosa and extends into the lamina propria (T2), beyond the muscularis propria (T3) or even invades surrounding structures (T4). For muscularis propria invasion, US and MR imaging had similar sensitivities; specificity of US (86%) was significantly higher than that of MR imaging (69%) [9]. For perirectal tissue invasion, sensitivity of US (90%) was significantly higher than that of CT (79%) and MR imaging (82%); specificities were comparable (75%, 78%, and 76%) [9]. For adjacent organ invasion and lymph node involvement, estimates for US, CT, and MR imaging were comparable (70%, 72%, 74%). Specificity estimates were also comparable (97%, 96%, 96%) [9].

However, the importance of T-staging has decreased with the widespread use of total mesorectal excision (TME; removal of the rectal cancer with the surrounding envelop of mesorectal fat bordered by the mesorectal fascia). For this treatment, determining the distance between tumor and mesorectal fascia (circumferential resection margin; CRM) has become crucial [10,11]. TME has been introduced as initially local tumor recurrence was high (approximately 28%) [12]. With TME the recurrence rate has decreased to 10-15% [12]. In Europe, mobile rectal cancers are treated by preoperative radiotherapy before TME and this has led to a further decrease of recurrence, especially for cancers in the mid-rectum (3.9% vs 14.9%; $p = <0.001$).
MRI can accurately determine the distance between tumor and mesorectal fascia and differentiate between patients with a wide circumferential resection margin, close margin and involved margin with accuracy rates of 92-100% and high reproducibility [13,14].

Nodal disease is a predictor for distant metastases and local recurrence [15]. Detection of nodal disease is therefore important. In rectal cancer, lymph drainage is upward along the superior rectal vessels to the inferior mesenteric vessels, while the lower rectum drains along the middle rectal vessels to the internal iliac vessels. In patients treated with TME, perirectal nodes are removed, but lateral nodes may lead to recurrent disease. Lateral lymphatic spread is more prevalent in low rectal cancer [16]. Radiotherapy is part of therapy to reduce the recurrence rate and in some countries dissection of the lateral nodes is used, although latter treatment has not gained much interest until now. Nevertheless, improved preoperative identification of lymphatic spread would be a major step forward in treatment of rectal cancer.
However, the results of MR imaging as well as endosonography and computed tomography with respect to lymph node staging are disappointing. The size criterion used to differentiate between benign and malignant nodes has serious limitations [17]. In a systematic review sensitivity estimates for US, CT, and MR imaging were comparably low: 67%, 55%, and 66%, respectively

[9]. Specificity values were also comparable: 78% for endoluminal US, 74% for CT, and 76% for MR imaging. Improved lymph node criteria, such as presence of spiculated border, indistinct border and mottled heterogeneic pattern strongly correlated with positivity ($P < 0.001$), but still have limitations [18]. The use of ultra small iron oxide particles (USPIO) has shown promising results [19].

Other developments in MR imaging of rectal cancer include dynamic contrast-enhanced imaging with pharmacokinetic tracer-exchange analysis, diffusion and spectroscopy. Dynamic contrast-enhanced imaging with pharmacokinetic tracer-exchange analysis leads to physiologic parameters that allow functional characterization of changes in the tumor microvasculature (e.g., tumor angiogenesis). Initial papers have shown that these parameters change early during the course of radiation therapy [20] and to be related to the tumor response to chemoradiation combination therapy [21,22]. Dynamic contrast-enhanced-MRI–derived endothelial transfer coefficient surface area product (K^{PS}) values show significant radiation therapy related reductions in microvessel blood flow in locally advanced rectal cancer [23]. These findings may be useful in evaluating effects of radiation combination therapies (e.g., chemoradiation or RT combined with antiangiogenesis therapy), to account for effects of RT alone [23].
In a diffusion weighted imaging (DWI) series of 14 patients with locally advanced rectal cancer a strong negative correlation was found between mean pretreatment tumor water ADC and percentage size change of tumors after chemotherapy ($r=-0.67$, $p=0.01$) and chemoradiation ($r=-0.83$, $p=0.001$) [24]. Persistence of low ADC in responders after chemotherapy could represent loss of a non-viable fraction of the treated tumor. In 34 patients with primary rectal carcinoma (cT3) undergoing preoperative chemoradiation, pretherapeutic perfusion indices and apparent diffusion coefficients were obtained, with significant differences between responders and non responders for mean perfusion index [25]. Data on spectroscopy is rectal cancer are limited. In advanced rectal cancers, choline and lipid peaks are found, with the maximum peak height dominated by the lipid methylene peak [26]. This lipid resonance has previously been associated with necrosis and macrophage invasion, and is commonly associated with advanced clinical stage in colorectal and other malignancies. However, tumor size was a limiting factor to obtain an spectrum.

Perianal fistulas

Perianal fistulas primarily occur as the result of fistulous disease originating from the anal glands near the anal crypts (cryptoglandular hypothesis) or in patients with Crohn’s disease. Infection of the anal glands may result in abscess formation. This abscess may drain into the anal canal and resolve or may lead to the formation of a track. It is a relatively common condition with a prevalence of approximately 0.01%, predominantly affecting young adults [27]. Men are more affected, with a male:female ratio of approximately 2:1. Patients most commonly present with discharge (65%) but local pain due to inflammation is also common. However, some fistulas may be entirely asymptomatic.
The track may have a simple superficial course or may have a, intersphincteric course (i.e. course through the internal anal sphincter and than downward extension through the intersphincteric space), transsphincteric course (i.e. transversing not only the internal sphincter but also the external sphincter or puborectal muscle), supralevator extent or extrasphincteric extension (track to the rectum without involvement of the anal sphincter). Especially the latter conditions need imaging for proper treatment, as inadequate treatment may lead to recurrent disease. The surgeon has to be informed on the presence and number of tracks, extent, location of internal opening and presence of abscesses.

Present work up may include physical examination, examination under anesthesia (EUA), endosonography or MRI. Physical examination has significant shortcomings, especially in patients with recurrent disease. EUA can be used for determining the extent of the disease, immediately followed by treatment. However, EUA has limitations and disadvantages, mostly related to probing. Firstly, not all fistulas have an external opening that can be probed, while probing may miss secundaire tracks. It is well-recognised that missed extensions are the commonest cause of recurrence, which reaches 25% in some series. Thereby, forceful probing may lead to perforation such as of the levator plate, worsening the extent of the disease. Patients with recurrent disease are a particular case in point. They are most likely to harbor missed disease but are also most difficult to assess. Multiple failed operations are the rule rather than the exception with the result that digital palpation frequently cannot distinguish between scarring due to repeated surgery and induration due to an underlying extension.

Endosonography (possibly with hydrogen peroxide installation in the track) can be used for determination of disease extent. Initial reports were hopeful, but later studies were less conclusive especially when comparison was made to MRI [27]. Much of this discrepancy probably relates to operator expertise since endosonography is highly operator dependent. However, there are undoubtedly several areas where AES suffers specific disadvantages. For example, insufficient penetration beyond the external sphincter, especially with high-frequency transducers, limits the ability to resolve ischioanal and supralevator sepsis, with the result that endosonography may miss extensions from the primary tract. Distinguishing infection from (postoperative) fibrosis can be cumbersome at endosonography. Endosonography has good results in demonstrating the internal opening.

MRI has been demonstrated to be the optimal overall imaging technique, facilitating accurate identification of tracks and extensions as well as abscesses. Results of a prospective triple-blinded comparison of accuracy of AES, pelvic MRI, and surgical EUA in perianal Crohn’s disease showed that AES correctly classified fistulas in 91%, compared with 87% for pelvic MRI, and 91% for surgical evaluation [28]. Combination of any two of the three modalities increased accuracy to 100%. Another study, in which MRI and AES were compared with surgical findings, showed MRI to be superior to AES in classification of fistulas with sensitivities of 84% vs. 60% for the two modalities, and specificities of 68% and 21%, respectively [29]. In this study less than one-half of the study group consisted of patients with Crohn’s disease. When looking at this subgroup of patients, sensitivity and specificity of AES for primary fistulas were 73% and 25%, whereas for recurrent fistulas values were 69% and 20%. For MRI, sensitivity and specificity in primary fistulas were 91% and 50%, respectively; for recurrent fistulas, a similar sensitivity of 88% was reached, while a higher specificity of 80% was observed.
Several studies have indicated the (therapeutic) effect of MRI on outcome; in one study the therapeutic effect of MRI before EUA was 21.1% [30]. Their results showed that further recurrence of disease after surgery could be reduced by about 75% if surgery was guided by MRI. However, the authors did find drawbacks of MRI; superficial extensions can be missed, and difficulty locating the precise level on the internal opening was perceived, owing to inability to visualize the dentate line. In another study the additional clinical value of preoperative MRI was evaluated [31]. Results showed that MRI provided important additional information in 21% of all patients, while in patients with Crohn’s disease the benefit was 40%. Sensitivity and specificity for detection of fistulas was 100% and 86%, for abscesses 96% and 97%, for horseshoe fistulas 100% and 100%, and for internal openings 96% and 90%, respectively.

Fecal incontinence
Faecal incontinence can be defined as the involuntary loss of flatus, liquid or solid stool that is a social or hygienic problem. It is a commoner problem than generally is thought. While not life-threatening, faecal incontinence constitutes a substantial problem for those afflicted. The psychosocial consequences of this condition are overwhelming and include amongst others

diminished self-esteem, social isolation, and anxiety of having unexpected episodes. The embarrassment and humiliation it causes makes it a taboo for a numerous people. Imaging is an important part of the work up, as anal sphincter defects and external sphincter atrophy are common disorders. In many centers endosonography is used as initial imaging technique for detection of anal sphincter defects, with endoanal MR imaging as alternative technique. MRI has the advantage of a better delineation of the external sphincter, facilitating assessment of external sphincter atrophy.
Both endoanal ultrasonography and endoanal MR imaging has been validated physiologically, histologically, and intraoperatively, as accurate tools in mapping internal and external anal sphincter defects [32]. Some studies compared these competitive techniques for demonstrating internal and external anal sphincter pathology. Malouf and colleagues evaluated prospectively two-dimensional endoanal ultrasonography and endoanal MR imaging in 52 patients with fecal incontinence and reported that both techniques are comparable in diagnosing external anal sphincter defects [33]. Further, they suggested the inferiority of endoanal MR imaging in demonstrating internal anal sphincter defects. Another study compared retrospectively two-dimensional endoanal ultrasonography and endoanal MR imaging to surgery in 22 patients with fecal incontinence and found MR imaging to be the most accurate technique for depicting internal and external anal sphincter defects [34]. The reported results of these studies vary. Some of the variability can be attributed to differences in study design, patient population and in the level of experience of readers. A recent large prospective study of 237 patients demonstrated that both techniques are comparable while agreement for mapping EAS defects was fair [35]. The current consensus is that both techniques can be used for demonstrating defects of the anal sphincter complex [32].
A recent comparative study in 30 patients showed that external phased array MRI is comparable to endoanal MRI in demonstrating external sphincter defects, although sufficient reader experience is mandatory for both techniques [36].

Depicting external anal sphincter atrophy is of importance in patients with fecal incontinence as a previous study demonstrated that atrophy of the external anal sphincter at endoanal MRI is a negative predictor for the outcome of surgery of an external anal sphincter defect (anterior anal sphincter repair) [37,38]. In a recent study in 200 patients with fecal incontinence, EAS atrophy was demonstrated in 123 patients (62%), graded as mild in 79 (40%) and severe in 44 patients (22%). They had a lower maximal squeeze ($p=0.01$) and squeeze increment pressure ($p<0.001$) [39]. Patients with severe atrophy had a lower maximal squeeze ($p=0.003$) and squeeze increment pressure ($p<0.001$) than patients with mild atrophy. Further studies should address the clinical relevance of these findings in selecting patients for treatment. A recent comparative study in 30 patients showed that external phased array MRI is comparable to endoanal MRI in demonstrating external sphincter defects, although sufficient reader experience is mandatory for both techniques [40].

Since the pelvic floor muscles are closely aligned and the striated pelvic floor muscles are probably all supplied by the pudendal nerve, it is possible that lesions (i.e. defects and atrophy) involve not solitary the internal and external anal sphincter, but also the levator ani muscles (i.e. levator ani plate (iliococcygeus, pubococcygeus) and puborectal muscle). A recent study showed that compared to anal sphincter lesions puborectal muscle and levator ani plate lesions are relatively uncommon in fecal incontinent patients [41]. They present rarely in isolation and are not associated with incontinence severity or manometric findings. Awaiting future studies, endoanal MRI in patients with fecal incontinence can be restricted to assessing the anal sphincters.

Conclusion

MRI using T2-weighted sequences and external phased array coils are mainstay in anorectal imaging. New developments, such as pharmacokinetic analysis of contrast enhancement and diffusion weighted imaging, will increase the importance of anorectal MR imaging in management of patients with anorectal diseases.

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